NASA-CR-201069

TRANSPORTATION SYSTEMS ANALYSES

(NAS8-39209)

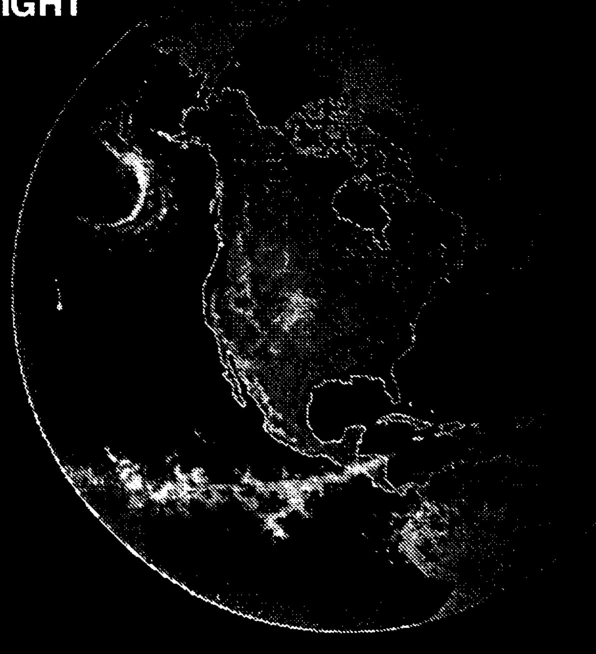
HIGHLY REUSABLE SPACE TRANSPORTATION (HRST)

Preliminary Programmatic Assessment

(DR-11)

MAY 1996

for
MARSHALL
SPACE FLIGHT
CENTER



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Transportation Systems Analyses
NAS8-39209

HIGHLY REUSABLE SPACE TRANSPORTATION (HRST)

A PRELIMINARY PROGRAMMATIC ASSESSMENT

Final Report (DR-11)

May 1996

Lockheed Martin Astronautics
Advanced Space Systems

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	22 April 1996	Technical 30 Nov 95 - 22 Apr 96

4. TITLE AND SUBTITLE

Transportation Systems Analyses (TSA): Highly Reusable Space Transportation Strategic Assessment (Final Report)

5. FUNDING NUMBERS

C NAS8-39209

6. AUTHOR(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

NASA / Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
Mr. Charles F Huffaker

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unlimited Distribution

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report overviews the strategic implications of the Highly Reusable Space Transportation (HRST) program. The analysis postulates the anticipated HRST market (window is 2006-30, with a 2015 focus). Next the analysis speculates on market "price of entry" for several potential markets.

HRST is envisioned as a NASA overlay to either the STS modernization or the on-going RLV initiative. Three NASA options are reviewed. An example HRST program (MagLifter + RBCC RLV) is assessed in terms of financial/political issues. The merits of HRST -vs- RLV are briefly examined. Finally, a Small Launch Vehicle (SLV) HRST application is reviewed.

14. SUBJECT TERMS	15. NUMBER OF PAGES
	31
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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FOREWORD

HRST: Preliminary Strategic Assessment

This document represents the final report for the Transportation System Analysis (TSA) - HRST Strategic Assessment (NAS8-39209). This effort is an add-on task to the basic TSA contract. The period of performance for the HRST Task was 30 Nov 1995 through 14 May 1996.

The opinions expressed in this report are those of the authors and do not necessarily reflect the Lockheed Martin Corporation position. The HRST analysis recognizes that NASA/MSFC has already selected high payoff ASTP technologies. With these technology selections having significant industry input, we believe the NASA/MSFC ASTP approaches are the appropriate choices. We envision that the HRST program will take selected ASTP technologies (for ETO only) to the next development level, e.g., a system prototype similar to the X-33 for the Reusable Launch Vehicle (RLV) program. Following the NASA prototype risk reduction phase, the technology becomes available to the commercial arena for further development. Consequently, the authors decided that rather than focus on technology development assessment and roadmapping, that they would focus this effort on trying to better understand the HRST strategic implications to NASA and the Nation. This includes market enablement and capture. The Huntsville Office of Lockheed Martin Astronautics views the HRST program as an overlay to existing and on-going new space transportation programs.

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HRST Task Lead

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1.0 INTRODUCTION

The objective of this study is to provide a top level assessment of the proposed Highly Reusable Space Transportation (HRST) system initiative. The concept assessment issues examined include performance analysis of Earth-to-Orbit (ETO) operation and associated basing concepts. Our focus is on the financial attractiveness of the HRST system initiative as an overlay to ongoing initiatives. An HRST system initial operating capability is no later than 2015. Finally, the results of our HRST system market capture study are presented, with conclusions regarding the potential direction and viability of current HRST system concepts and approaches.

Our topic is future ETO activity, and we begin by analyzing markets through 2020. Concentrating on Low Earth Orbit (LEO) activity, we look at payload classes between 20 and 40 Klbm, plus payloads of less that 1 Klbm. Topics addressed are core markets, programmatics, and competitiveness against conventional expendable launch vehicle (ELV) and planned reusable launch vehicle (RLV) services.

Our HRST system assessment study groundrules include:

- An HRST system time window focus for a 2015 IOC --- a 2030 IOC is not addressed
- X-33/RLV/EELV/ASTP funded beyond 2000
- The HRST system primary goal is dramatic ETO price reduction
- The HRST system focuses on reusability
- Leading HRST system technology candidates contained in Advanced Space Transportation Program (ASTP) include:
    - Rocket-Based Combined Cycle (RBCC)
    - MagLifter
    - Low cost upper stages
- The primary HRST system markets: Payloads from 20 to 40 Klbm, and ≤1 Klbm (LEO equivalent)

The HRST program will likely require ≤\$5B to IOC. This assumes that a Highly Reusable Launch Vehicle (HRLV) development (prototype plus EMD phase) can be fielded for substantially less than the RLV (\$6B-\$9B). Thus, a US Government (USG) and industry partnership (including initial flight guarantees) is very likely. Our study assumes that NASA will have the primary USG role in the HRST system. Specifically, NASA will provide primary funding up to at least the commercialization phase (e.g. through ASTP prototyping).

Several assumptions were made about the future global launch environment. First, ongoing USAF and NASA development programs are expected to remain in place into the next century. Should the maturity of these launch systems confirm expectations in operational cost, many new access-to-space markets could be exploited that were previously impossible to pursue. Concepts include the Evolved Expendable Launch Vehicle (EELV) system (to support USAF missions out through 2010), the X-33/RLV system (which has a 2004 IOC), plus potential launch systems evolving from X-34 development and the ASTP. Modernization of the commercial ELV system community is also assumed to continue. This would result in cost-effective competition for any reusable system at least through 2010. This ELV competition will come from both domestic and foreign systems. These activities underscore the concern that a new launch system would enter an ETO market environment already saturated by developing or on-line launch systems, and remaining saturated well into the next century. These current launch systems can be expected to have priority over any new start, both in investment dollars and likely in initial market share.

Certainly not all of these initiatives will prove successful. However, it is likely that one or more will, and thus play an important role in evolving or revolutionizing space access. Part of the outcome hinges upon payload developments. Key here will be the degree to which spacecraft

(S/C) development and recurring costs are systematically reduced in all markets. Similarly, the advent of paradigm-breaking markets such as Teledesic is also critical. In short, the interplay of advances in ETO and S/C systems will determine the future brightness of the space arena.

As a general principle, we are convinced that a reusable (fully or partially) ETO transportation system is the way of the future. We see limited gains in ELV, especially in the 20 to 40 Klbm LEO market. Our own experience in this market technology tells us that reusability is clearly the appropriate approach. Furthermore, we define the HRST program as one embodiment of ASTP technology into government/commercially development ETO systems. Indeed, one could say that the HRST program is the commercially viable aspect of ASTP. The selected ASTP technologies being pursued by NASA, whether RBCC or MagLifter, hybrid motors or other booster motors, will drive the resulting cost of the HRST system and determine its commercial future and form. In this report we will refer to the HRST program as an overarching program incorporating ASTP technology. The actual vehicle(s) that might result from the HRST initiative we will define as HRLV (Highly Reusable Launch Vehicle).

The first step in the process is to forecast the access to space market place.

2.0 TRAFFIC MODEL FORECASTS

The strength of any reusable space transportation system concept stems from the belief that it will require dramatically lower operating costs (compared to today's launch fleet) and is capable of rapid turn around. Thus, a very cost-effective, high flight rate potential exists, expected over time to open new space access markets. The domestic expendable launch vehicle (ELV) market today (both government and commercial) is expensive, but highly price-competitive and generally reliable. The substantial capture of this ELV market that is a critical first step toward making any HRST system program successful. An HRLV system can only enable new markets after establishing its credentials in existing markets. For a multi-billion dollar HRLV development, this likely requires some form of launch guarantees to gain investor support (RLV is an analog).

2.1 Core Markets/Forecast (beyond 2000)

2.1.1 Methodology

Our approach to HRLV/RLV market capture is incremental in nature. We first establish a "core" market base (see Figure 2-1). This core represents a conservative estimate of the known market. It consists of US Government (NASA plus DoD) and worldwide commercial payloads. The HRLV/RLV system must initially capture major segments of this market, from today's incumbents, in order to rationalize the vehicle investment payback. We will discuss this core market in Section 2.1.2

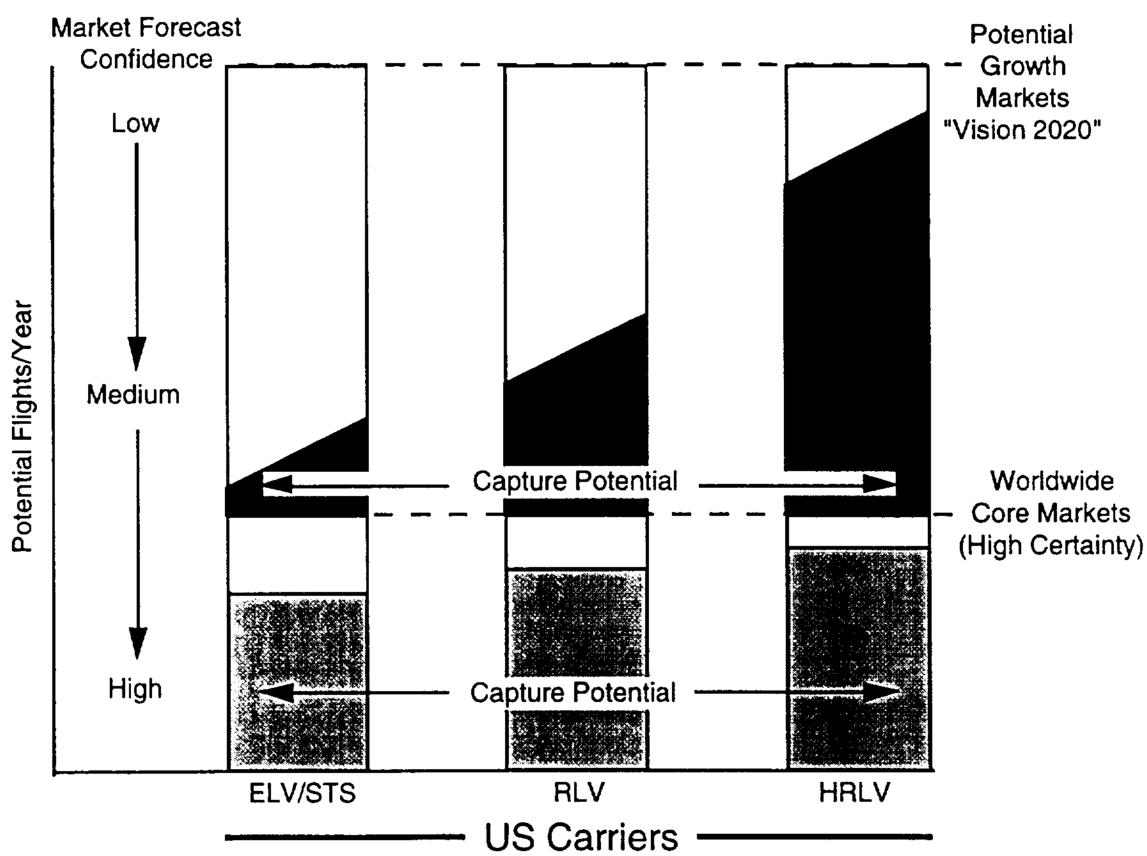


Figure 2-1: Core Market plus Growth Market Capture

We see the new, growth markets as a series of overlays to the core. These markets include widely disparate missions, from Teledesic to space tourism. Both US Government (USG) and commercial payloads are addressed. The ability to enable these markets is dependent upon the HRLV/RLV pricing structure (see Section 2.3).

2.1.2 Core Market Assessment

The forecasted core domestic space launch market can be partitioned into several components based upon payload category/user:

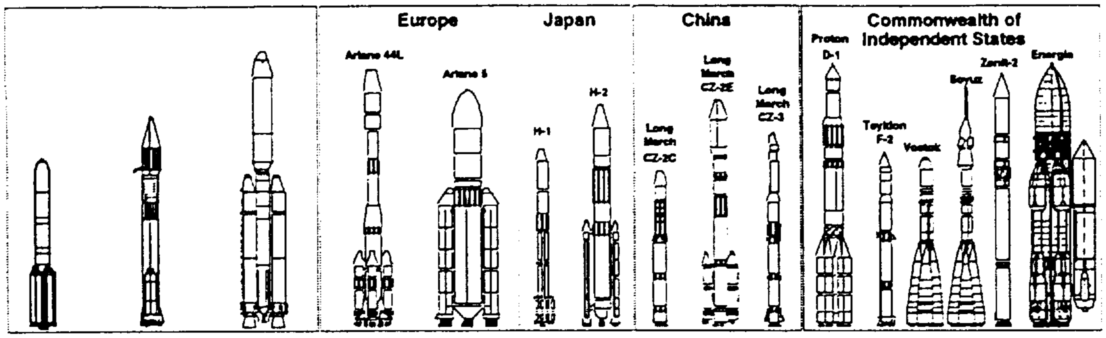
- US Government (USG)
  - DoD (USAF/USN primarily)
  - Intelligence
  - Civil (e.g. NASA)
- GTO Commercial (primary communications/broadcast)
  - US Satellites
  - International/Foreign Satellites
- LEO Commercial (communications/remote sensing)
  - US and Foreign new markets
  - Constellations communication consists primarily of large LEO (polar)
  - Remote sensing satellite are single, LEO (polar)

To service these markets today, the US relies on its fleet of ELVs plus the STS. In aggregate, the US will launch approximately 30 flights per year in the medium, intermediate, and heavy launch vehicle classes (including STS) during the mid-1990s. Typical annual flight rates are broken out as follows:

- STS = 7
- Titan IV = 3 - 5 - HLV (Heavy Launch Vehicle)
- Atlas = 8 - 10 - ILV (Intermediate Launch Vehicle)
- Delta = 8 - 16 - MLV (Medium Launch Vehicle)

Smaller ELVs (e.g. SLV) would add to this list, including such vehicles as LMLV, Taurus, Conestoga, and Pegasus.

In our support of the current X-33/Reusable Launch Vehicle (RLV) program, an investigation was conducted to determine the credibility of an RLV take-over of the US market from the above incumbents. We elected to exclude SLVs from our RLV capture analysis due to the much smaller delivery capacity of SLVs, and because the RLV is not expected to be price competitive against SLVs. Thinking more globally begs the question whether an RLV system can successfully compete with the world's ELV fleets, illustrated in Figure 2-2. Note that the ELV payloads span a huge range, from 7 to 48 Klbm to LEO. It will be challenging for any reusable launch system to successfully compete across such a wide payload range.

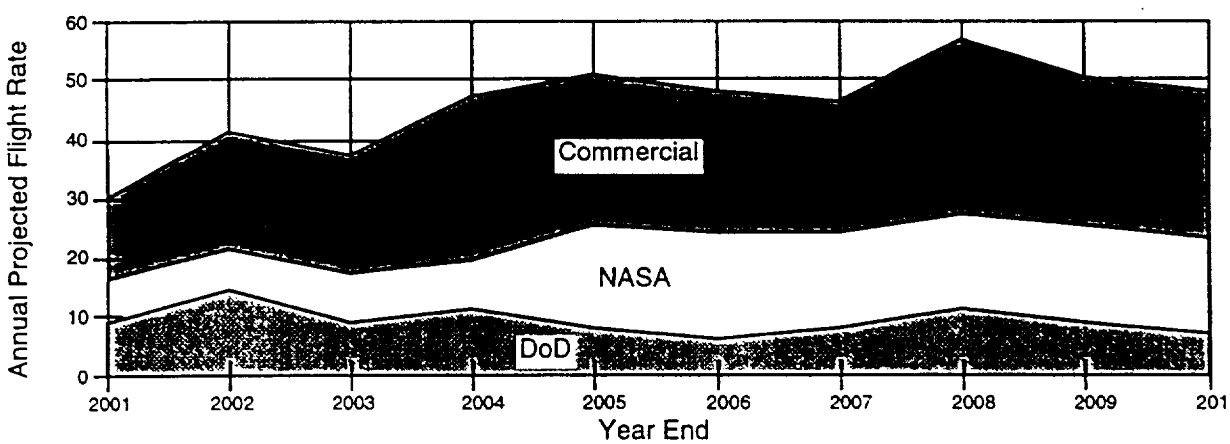


		6920 / 6925	7920 / 7925	Atlas I	Atlas II	Atlas IIA	Atlas IIAS	Titan III	Titan IV	Ariane 40	Ariane 44P	Ariane 44L	Ariane 5	H-1	H-2	CZ-2C	CZ-2E	CZ-3	Proton D-1	Tsyklon F-2	Vostok	Soyuz	Zenit-2	Energia
GLOW (K lbs)		480	506	362	414	414	518	1,500	1,900	529	789	1,040	1,570	308	582	421	1,023	446	1,550	418	639	630	1,012	5,300
Payload (K lbs)	LEO	8.8	11.1	12.3	14.1	15.7	18.5	32.0	39.0-47.7	10.8	15.2	21.1	39.8 †	7.0	23.0	7.0	20.9	11	44.1	8.8	10.4	15.4	30.3-34.8*	194
	GTO	3.2	4.0	5.0	5.8	6.2	7.7	10	14.0-19.0	4.2	6.6	9.3	15.0	2.4	8.8	2.2	9.9	3.3	12.1	-	-		8.4	-
Payload Envelope - Diameter (ft) - Length (ft)		8.3 ~10	9.2 ~16	11.0 (MPF) / 12.0 (LPF) ~13-25 / ~14-30 (LPF) (LPF)				13.1 ~30	16.7 ~40		12.0 ~13 - 22		15.0 39.3	7.2 ~9 - 15	12.1 ~28	10.1 ~7 - 14	12.5 ~10 - 20	7.8 - 8.9 ~6 - 14	10.8 - 12 ~13 - 18	7.5 ~12	7.4 ~13	9.3 ~22	10.8 ~18 - 28	22 138

* Performance based on launch from current launch sites.

Figure 2-2: The World's ELV Fleets

Figure 2-3 highlights our estimate of the global core market beyond 2000. This is the core market that the HRLV system must initially dominate before it can enable new growth markets. As noted, only MLV, ILV, and HLV (including STS equivalent) payload classes are included. Furthermore, all foreign government pre-assigned missions have been eliminated. Primary source data comes from COMSTAC (May 1995), an assessment of ISS support requirements, and the Early Expendable Launch Vehicle (EELV) RFP (May 1995). The cyclic variations reflect periodic replenishments of different satellite constellations (GPS, Big LEO, etc.).



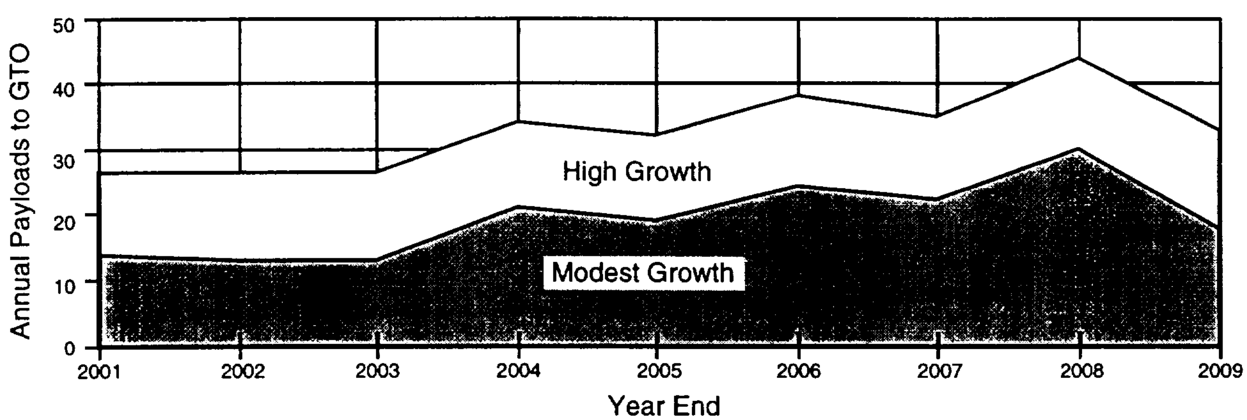
Assumptions:
- Total Market (Medium, Intermediate, Heavy)
- Does not Include Foreign Government Launches
- DoD/NASA Market Based on EELV Mission Model (4/95)
- NASA Flights Account for STS to RLV Transition (7 - 15)
  - STS Non-ISS Flights (2/yr) Dropped From RLV Requirement
- Commercial Market from 5/95 COMSTAC Forecast. Includes Estimates (Modest Growth) For Both GTO and Big LEO (no Mega LEO)
- Single Manifested Payloads

Figure 2-3: Global Market Forecast

A steady state demand of ~50 missions per year is forecasted by 2010. Some of the commercial missions (e.g. GTO) could be dual manifested, thus reducing the number of flights plotted. The increase in NASA missions is attributable to STS-to-RLV phasing. The seven STS flights per year (five for ISS support) are transitioned to 15 RLV flights (all for ISS support). NASA and DoD payloads are obviously committed to US carriers.

The GTO and Big LEO classes (e.g. Iridium, Globalstar, etc.) were included in the commercial market segment. For our core market analysis, the Mega LEO class (e.g. Teledesic) was excluded. As a market segment, the commercial market offers the greatest (i.e. largest number of missions) long-term growth for a reusable launch system. Today, this market segment consists primarily of GTO communications and direct TV broadcast satellites.

Figure 2-4 (commercial, worldwide GTO market) shows that over the time window of 2001 to 2009, the Modest Growth Model averages 19.3 flights per year, while the High Growth Model averages 32.8 flights per year. Over 85% of both models are populated with satellites in the 4 to 10 Klbm classes. Note the cyclic nature of the GTO trend. Following a broad peak in the mid-late 1990's, we see a valley in the trend (2001 to 2003) followed later by another broad peak. The period is from 8 to 10 years. Interestingly, the 1995 COMSTAC shows an increase of approximately 20% in flight rate over their 1994 report. Before selecting the COMSTAC model, other commercial ELV forecasts were reviewed including Arianespace and CSP Associates. Our core market adopts a forecast intermediate between Modest Growth and High Growth, based upon discussions with our International Launch Services group.



COMSTAC Membership:
- Aerospatiale
- Arianespace
- AT&T
- GE Americom
- Hughes
- Intelsat
- Lockheed Martin
- Loral
- Matra Marconi Space
- MDC
- TRW

Figure 2-4: COMSTAC Commercial GTO Forecast

The total commercial market forecast consists of the GTO market plus two other emerging new markets, Big LEO and remote sensing. Extrapolating the COMSTAC model beyond 2005, five MLV class flights per year were added (2002 - 2005 and 2008 - 2011) to account for deploying new blocks of Big LEO payloads (specifically Iridium and Globalstar). At least one market forecast (Teal Group) predicts that Big LEO (and Mega LEO) will cause some erosion the GTO market. For the purposes of establishing a baseline core traffic model for the RLV program, we assumed no commercial remote sensing satellite deployments in the MLV or greater classes. We believe these launches are primarily aimed at the SLV class.

A listing of the principal baseline (core market) payloads is shown in Figure 2-5. It displays ~45 flights/year. The source for most of this data is the EELV RFP. This figure provides important information on each of the payloads.

					FINAL ORBIT			
Category	Payload	Coast	Orbit	Throw Wt (lbs.)	Apogee (NM)	Perigee (NM)	Inclination (Degrees)	U.S. Flts/Yr
AFSPC	•SBIR GEO	East	GTO	7450	19324	90	GTO	0.8
	DSCS	East	GTO	6125	22640	3568	GTO	0.2
	GPS IIF	East	GPS	4250	10998	100	55	3.0
NASA	• Discovery	East	Planetary	2000	N/A	N/A	GTO	0.3
	EOS AM	West	Sun-Synch	11220	380	380	98.2	0.2
	EOS PM	West	Sun-Synch	7000-8000	380	380	98.2	0.1
	EOS CHEM	West	Sun-Synch	7900	380	380	98.2	0.2
Other DoD	MLV-N	West	Polar	6000	500	500	90	0.4
	DMSP 5DIII	West	Sun-Synch	4100	450	450	98.2	0.5
	ADV MILSATCOM	East	GTO	7900	19324	90	GTO	0.5
	NPOESS	West	Sun-Synch	4000-5000	450	450	98.2	0.4
Support	MISSION A	East	GTO	8500	19324	90	GTO	0.9
	MISSION B	East/West	LEO	17000	100	100	63.4	0.3
Commerical	• COMLSAT A	East	GTO	4060	19323	100	GTO	2.5
	• COMLSAT B	East	GTO	6-12000	19324	90	GTO	6-18
	• BIG LEO	West	Polar	11000	420	420	86.4	2.5
	• MEGA LEO	West	Polar	11000	420	420	82.0	TBD
ISS (Space Station)	mPLM	East	LEO	25000	244	244	51.6	9.0
	CM (Crew Module)	East	LEO	25000				4.0 RLV
	ULC	East	LEO	18000				2.0

Note 1: RLV delivers payloads to 100 X 100 nm at indicated inclination; upper stage/apogee kick motor makes final orbital insertion. Except: ISS for which RLV delivers payloads to ISS

Note 2: For GTO/GPS missions RLV delivers a mass of ~ 4.4 X throw wt to 100 X 100 nm

Note 3: For polar missions RLV delivers a mass of ~ 1.5 X throw wt to 100 X 100 nm

Shaded Missions: EELV captures these classes prior to and including the year 2011 (assumption)

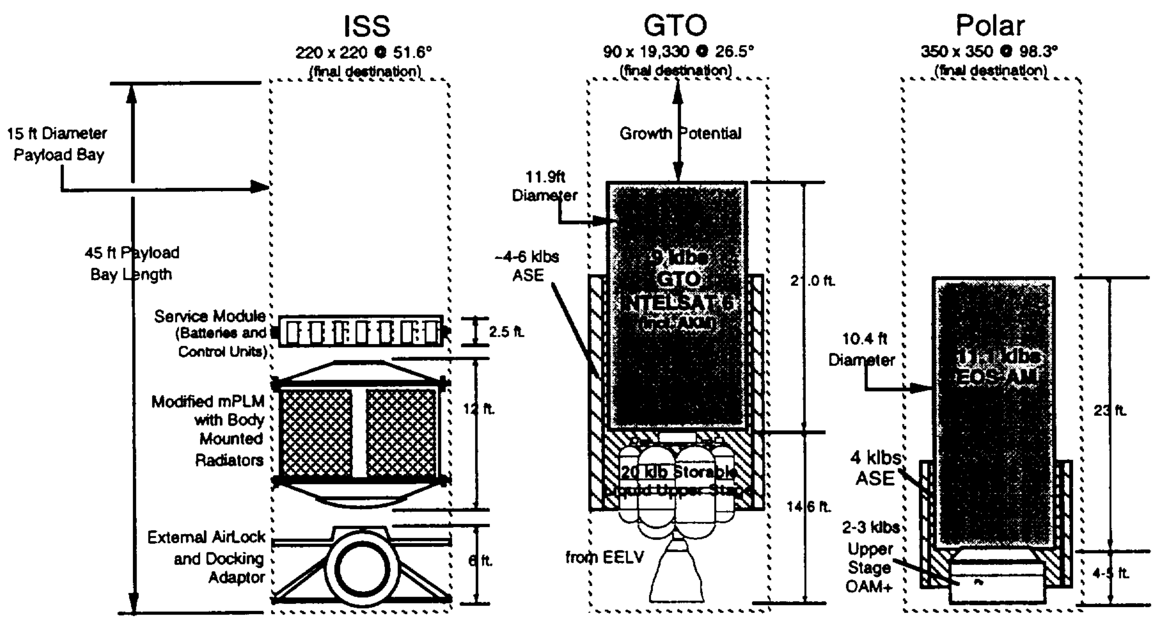
Figure 2-5: RLV "Most Likely" Traffic Model (>2010): Core Market

2.2 Payload Drivers Size HRLV/RLV

To capture all of the core missions specified in Figure 2-5, we simply went down that list to determine which payloads actually drive RLV performance (mass delivery) and configuration (payload size). The nominal payload drivers are shown in Figure 2-6.

Recall that the NASA RLV CAN stipulated ~25 Klbm delivery to ISS (i=51.6°, h<244 nm). We sized our RLV to meet this requirement. Notice that three drivers (one for ISS, GTO, and POLAR) are displayed. Each payload, in its own way, is a "driving" mission for RLV.

The mPLM (mini Pressurized Logistics Module) with support ASE (including docking mechanism) requires 24 Klbm delivery to ISS. The polar mission driver is shown to be the EOS-AM (11 Klbm). Although this particular payload is scheduled for 1998, we believe it is representative of ≥2004 USG polar payloads (NASA, USAF, and Intelligence). Fully outfitted in the payload bay, it should weigh ~18 Klbs. This is very close to the maximum delivery capability of the RLV to this inclination. Notice too, that a small U/S (upper stage) is required to transfer the payload from the 100 x 100 nm RLV orbit to the final EOS-AM destination (350 X 350 nm). Not shown, multi-manifested Teledesic (Mega LEO) could also drive this mission (both mass and volume).



	ISS	GTO	Polar
Mass to Orbit (klbs)	24	35	18
Packaged Length (ft)	< 25	39	32
Packaged Diameter (ft)	15	15	13

* All Payloads Assume 2 ft. Clearance on Either End

Figure 2-6: RLV Payload Drivers

The GTO mission (represented by Intelsat VI) provides the payload bay length driver (>30 ft). All GTO missions will require a storable U/S (see Figure 2-6). Thus, a 9 Klbm GTO satellite requires an RLV capability of over 35 Klbm to LEO. Based on mass, the RLV should be able to deliver most foreseeable commercial satellites (≤11 Klbm). However, payload bay length could become an issue. We have recently become aware of an emerging commercial GTO trend to split the ILV market:

- ILV: 6.0-8.4 Klbm GTO
- ILV+ (or HLV): 9.0-11.0+ Klbm GTO

Exactly how these two markets will be populated ≥2004 is unknown, but we believe our larger payload bay serves us well should this trend occur. Similarly, if Titan IV payloads are downscaled, a large payload bay is very beneficial. We have baselined a new storable U/S which we are currently proposing in our EELV contract with the USAF. As indicated in Figure 2-6, we have baselined a payload bay which is 15 ft (diameter) X 45 ft (length). We believe this is prudent in light of: future payload length uncertainty, U/S configuration, and potential multi-manifesting of payloads.

2.3 Vision 2020: Potential HRLV/RLV Growth Markets

Our Vision 2020 model provides an optimistic prediction of domestic and foreign launch traffic from 2004 (predicted year for RLV introduction) to 2020, in order to discover futuristic reusable space transportation system markets. This market includes both the core market previously addressed, plus new growth markets for the HRLV/RLV system. The Vision 2020 model should be contrasted with our "core" (conservative, "must win") market discussion in Section 2.1

This futuristic traffic model was derived from several sources, including CSTS (Commercial Space Transportation Study), and our ongoing X-33 Phase I analysis. Potential markets for the HRLV/RLV system would include:

- Core Markets:
  - ISS
  - NASA/other (Delta)
  - DoD/GTO (Atlas and Titan IV)
  - DoD/Polar (Delta)
  - Commercial/GTO
  - Big LEO (Commercial, Polar)

plus,

- Growth Markets:
  - LMI (Lunar Mars Initiative) LEO
  - DoD/TAV
  - Mega LEO (Commercial, Polar)
  - Free-Flyers (Commercial)
  - Tourism (Commercial, Manned)
  - Business Park (Commercial, Manned)
  - Nuclear Waste Disposal (Commercial)

Most are self-explanatory, but a few comments are in order. First LMI LEO is the revisitation of the Lunar/Mars Initiative. For our study we assumed that the ISS would eventually be converted into a LEO space node for flights to the moon/planets. Our traffic model then attempts to estimate the traffic up to this LEO node to support these missions.

Next, although we list HRLV/RLV for DoD applications (e.g. TAV), we will exclude it from our traffic model capture because it is likely to be operated independently of all others shown. Exactly how many missions of each category HRLV/RLV can capture remains to be seen. Market price and vehicle availability/cost will largely dictate mission capture. Our preliminary conservative analysis suggests that the last four categories (Free-Flyers, Tourism, Business Park, and Nuclear

Waste Disposal) are not likely to occur in the time frame for RLV because of market price/cost considerations (see Section 3.1.2). Free-Flyers will probably be manifested as a second payload and therefore will not be displayed as separate missions, due again to price/cost considerations. Several of these four excluded missions could conceivably be captured by HRLV, if the pricing/cost were appropriately low (Section 5.2).

The potential total global launch vehicle traffic from 2004 to 2020 is shown in Figure 2-7. In this figure, the global traffic is partitioned into various mission categories (e.g. ISS, commercial GTO, Big LEO, etc.). It addresses markets which are expected to be of potential government and commercial interest, especially if a mature RLV system exists. The predicted annual launch rates for each mission category is provided. Launch vehicle systems included in the model are the STS and ELVs of MLV, ILV or HLV class. Also included are HRLV/RLV systems (both domestic and foreign) that are assumed under development and competing with the ELV classes for predicted markets. ELVs of the SLV class (vehicles with <2000 lbm payload capacity) are not addressed. We will address this class separately (see Section 6.0). Figure 2-7 assumes a general and gradual increase in launch vehicle traffic over the first 10 years of the model, with a significant increase in launch activity after 2015.

Missions (Total Global Traffic)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
• ISS	15	16	21	23	23	23	23	23	23	23	21	12	0	0	0	0	0
• LMI LEO	0	0	4	4	4	4	0	0	0	0	4	8	30	35	35	35	35
• NASA/other	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
• DoD/GTO	5	3	5	5	6	4	4	4	3	3	4	2	2	2	3	2	1
• DoD/Polar	4	3	3	4	5	3	5	6	3	5	5	3	5	4	5	4	3
• Foreign Government	18	11	15	12	16	10	12	9	10	10	9	9	11	9	9	10	10
• Commercial/GTO	21	19	24	22	30	18	18	20	23	29	31	32	34	32	31	26	27
• Big LEO (Commercial, Polar)	7	4	0	0	7	7	7	2	0	0	5	5	5	0	0	0	0
• Mega LEO (Commercial, Polar)	56	1	6	6	59	58	16	16	61	61	21	21	63	66	21	21	55
Annual Foreign Totals	81	29	36	28	57	40	26	27	51	59	42	40	72	72	45	42	76
Annual US Totals	44	29	43	49	94	88	60	54	73	73	59	53	79	77	60	57	61

Figure 2-7: Total Potential Global Traffic: 2004 to 2020

As RLV system technology and operation matures, both domestically and abroad, ELV systems globally can be expected to be gradually replaced. An approximate seven year global transition period can be expected, beginning around the 2008 time frame, and progressing through 2015. During this time, RLV systems will experience increased operability and decreasing costs, encroaching on traditional ELV markets. With some possible exceptions, markets requiring ELV services will be minimized over time, subsequently reducing ELV activity to an insignificant segment of the launch traffic after 2016. With the lower cost RLV systems finally dominating the global launch market, a significant increase in overall launch activity is predicted after 2015.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Missions (STS, MLVs, ILVs, and HLVs)																	
• ISS	13	12	10	8	8	8	7	5	3	2	1	0	0	0	0	0	0
• LMI LEO	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
• NASA/other (Delta)	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
• DoD/GTO (Atlas and Titan IV)	5	3	5	5	6	4	4	3	0	0	0	0	0	0	0	0	0
• DoD/Polar (Delta)	4	3	3	4	5	3	5	4	0	0	0	0	0	0	0	0	0
• Foreign Government	18	11	15	12	16	9	10	8	7	7	6	4	1	1	0	0	0
• Commercial/GTO	19	12	15	7	14	3	2	5	7	11	5	2	0	0	0	0	0
• Big LEO (Commercial, Polar)	7	4	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0
• Mega LEO (Commercial, Polar)	56	1	3	3	29	26	5	4	14	7	1	1	0	0	0	0	0
Annual Foreign Totals	81	29	36	28	57	37	22	21	26	23	14	7	1	1	0	0	0
Annual US Totals	42	18	16	12	24	19	14	11	5	4	0	0	0	0	0	0	0
Missions (RLVs)																	
• ISS	2	4	11	15	15	15	16	18	20	21	20	12	0	0	0	0	0
• LMI LEO	0	0	4	4	4	4	0	0	0	0	3	8	30	35	35	35	35
• NASA/other	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
• DoD/GTO	0	0	0	0	0	0	0	1	3	3	4	2	2	2	3	2	1
• DoD/Polar	0	0	0	0	0	0	0	2	3	5	5	3	5	4	5	4	3
• Foreign Government	0	0	0	0	0	1	2	1	3	3	3	5	10	8	9	10	10
• Commercial/GTO	2	7	9	15	16	15	16	15	16	18	26	30	34	32	31	26	27
• Big LEO (Commercial, Polar)	0	0	0	0	5	5	5	0	0	0	5	5	5	0	0	0	5
• Mega LEO (Commercial, Polar)	0	0	3	3	30	32	11	12	47	54	20	20	63	66	21	21	55
Annual Foreign Totals	0	0	0	0	0	3	4	6	25	36	28	33	71	71	45	42	76
Annual US Totals	4	11	27	37	70	69	46	43	68	69	59	53	79	77	60	57	61

Figure 2-8: Predicted ELV and RLV Global Traffic: 2004 to 2020

The Vision 2020 model identifies future market interests and activity levels of our international launch system competitors. Figure 2-9 identifies various markets, the amount of mission activity associated with those markets, and the source of that activity from 2004 to 2020. Potential leading competitors include:

- European Community, with Arianespace ELVs and future ESA LV development including a European RLV (or potentially HRLV)
- Commonwealth of Independent States (CIS), with Proton, Zenit, Soyuz and a potential RLV development
- Japan, with the H-2 ELV, H-2 upgrades or RLV system
- Peoples Republic of China (PRC), with the Long March ELV series (RLV capability before 2020 doubtful unless purchased)

As in other figures, domestic RLV systems eventually dominate all access-to-space markets identified. The European Community is seen as our nearest competitor in the long term, and most active in the Commercial and Mega LEO markets.

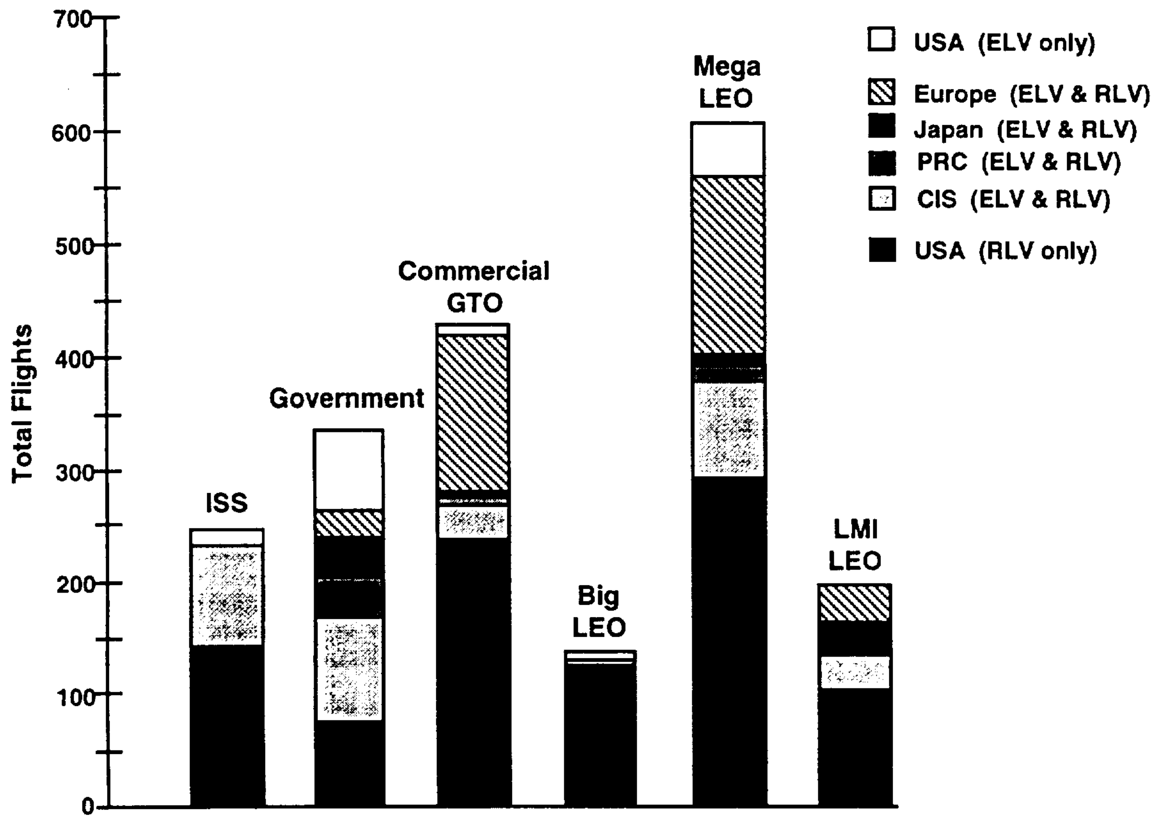


Figure 2-9: World Market Distribution: 2004 to 2020

Many of the futuristic model markets can only be enabled if ETO prices are slashed far below (>10 times) today's prices. In fact, it is unclear at this point whether our price projections for our RLV concept are sufficiently low. We have adopted much of the CSTS (1993-94) market enablement projections to establish our thresholds.

More importantly, our recent RLV work and ongoing Atlas IIAR development tells us that it is not simply a matter of developing a new launch vehicle and the market beating your door down. As with any major new development, it is cash flow and financial exposure that ultimately energizes (or not) the program. And in the case of a multi-billion dollar program, it is unlikely that the commercial sector (industry plus investors) will go it alone, especially if the risk is perceived high. Thus, the USG must be a willing partner, at least up to the point where risk is sufficiently retired so that the commercial sector can assume the primary development responsibility. Even then the USG must sometimes guarantee some level of launch commitment to make the market risk acceptable. The current RLV program analog appears as a credible model for this purpose (HRST). Note that Atlas IIAR/Delta III/SeaLaunch initiatives are inappropriate models because of smaller investments, lower technical risks, and lower market risks.

The potential HRLV market capture would notionally begin with RLV market capture, and incrementally expand on it to the degree that its pricing structure and flight dependability warranted. Thus, it should at least capture the RLV totals shown in Figure 2-8, ultimately expanding the market share. Additionally, several of the growth missions excluded in the RLV market assessment (e.g., Tourism, etc.) may materialize. The next section attempts to correlate pricing thresholds with market segment enablement. Examples from today's core markets to growth markets are addressed.

3.0 CAPTURING THE MARKET: HRLV/RLV PRICING

Capturing large portions of current markets for transportation to and from space, while at the same time opening space to new markets, is a critical link in the integrated strategy for making HRLV/RLV a viable business. A primary strength of the HRLV/RLV concept stems from the fact that it will offer dramatically lower operating costs when compared to today's launch fleet. As a fully reusable system, operating costs are almost entirely fixed, so that the marginal cost to fly each additional flight is small when compared to expendable systems. Additionally, the high degree of operability inherent in the reusable design allows rapid flight-to-flight turnaround, resulting in a capability to sustain significantly higher flight rates relative to current systems. As shown in Figure 3-1, these system attributes have a significant impact on cost per flight, and, therefore, potential profitability.

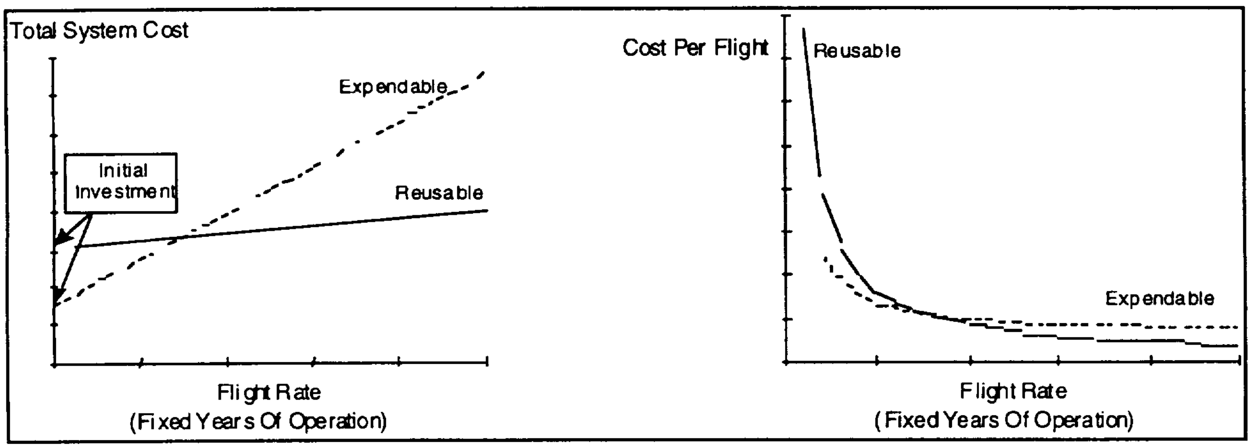


Figure 3-1: Launch System Cost Sensitivity to Flight Rate

As illustrated, the HRLV/RLV must fly often to significantly reduce recurring costs. Designing the system to sustain high flight rates is important. However, if the demand for transportation does not support high flight rates, the under-utilized system will quickly become extremely costly and potentially not sustainable in a commercially competitive environment. Accordingly, our market capture strategy is key to the successful development and implementation of any HRLV/RLV business plan. Our market capture strategy can be summarized as a three step approach:

1. <u>Define core markets</u>: Characterize the core markets for space transportation. Identify who the customers are, what requirements they maintain in terms of payload characteristics, number of payloads, destinations (e.g., altitude and inclination), return payloads, inclusion of manned capabilities, and other relevant requirements. Core markets are considered existing segments and forecasted continuation and expansion of those segments, such as NASA - International Space Station (ISS) and science missions, DoD - communication and intelligence missions, and Commercial - geosynchronous communication missions, and near term, large-scale, polar-orbiting communication systems.

2. <u>Provide a responsive product</u>: Design and build an HRLV/RLV system which is responsive to customer needs. The system must provide a competitive launch service which meets a wide range of customers with many disparate needs. This element of the strategy must consider all elements of the HRLV/RLV system, including the vehicle, basing, and operations concepts.

3. <u>Develop a viable pricing structure</u>: Develop a pricing structure which balances the need for low prices to compete in current markets and open important new markets, with the need to generate revenues sufficient to ensure recovery of the high initial investment. Recognize and exploit the sensitivities, or "elasticity", within the various market segments.

The market capture strategy must provide a credible, robust story persuasive to all stakeholders, underpinning each facet of the proposed markets, and including solid rationale addressing the key issues associated with each market segment.

3.1 Enabling Future Markets: Entry Price Thresholds

In assessing the HRLV/RLV system potential to capture future markets, we cursorily investigated what we call: "Entry Price Barriers" and how well our RLV concept measured against these barriers. We examined several of the "Second Wave" and "Third Wave" markets (longer term, higher risk).

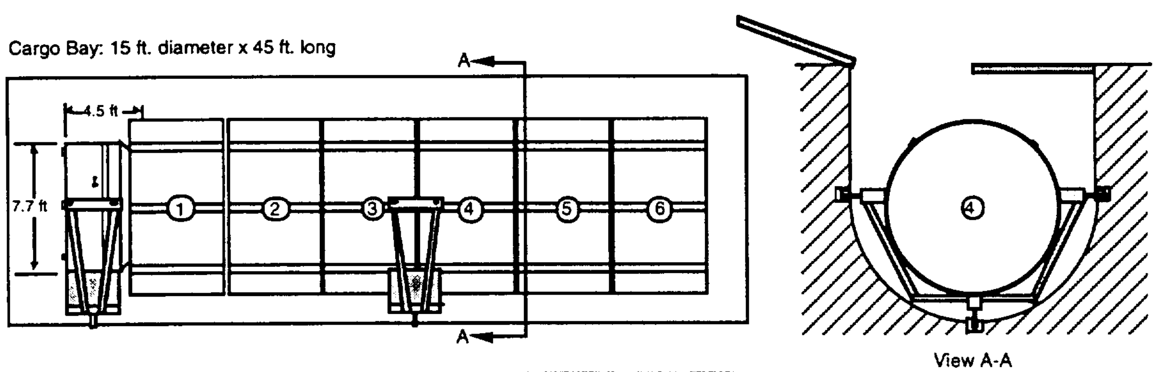
First, how well does our baseline RLV concept meet the core market entry price barriers? To recap briefly:

- ELV GTO (ILV) Market (circa 2004): $7500/lbm (today ~$11000/lbm)
- RLV GTO (ILV) Market: $4500 - $5600/lbm

Corresponding recurring costs for this GTO class: ELV ($6600/lbm) and RLV (~$1000/lbm). Thus, we feel comfortable that our RLV concept is fairly robust in the core markets. Next, we examined Teledesic and Space Business Park/Tourism as examples of Second and Third Wave growth markets, respectively. We will also assess the HRLV system potential in all three markets.

3.1.1 Teledesic: Second Wave

An overview of the RLV - Teledesic manifest is shown in Figure 3-2. As illustrated, we can co-manifest up to six individual S/C.



6 Teledesic (packaged)		12,000
6 Teledesic Spacecraft	12,000	
Transfer Stage (modified OAM)		2,546
Dry Weight	1,430	
Propellant	1,116	
Airborne Support Equipment		3,000
		17,546

Figure 3-2: RLV Co-Manifesting of Teledesic

For Teledesic, we propose a customer price initially of $30M/flight. This equates to $2500/lbm to polar orbit or alternately $5M/satellite. Teledesic has stated a goal of $3.3M/satellite. Best estimates are that ELV delivery would cost Teledesic between $8 - $15M/satellite. Thus, we believe that RLV not only is super price competitive (versus ELV), but comes close to meeting the Teledesic's very optimistic goals. Analysis of revenues suggest that during deployment years, RLV could generate over $900M/year from Teledesic alone (30 flights/year). Gross profits derived from Teledesic (Revenue - Costs) could reach $600/year. This level of RLV support for Teledesic assumes that RLV would capture 40% of the 840 baseline deployment. If Teledesic offered a greater deployment share (~60%), we could drop prices to say $25M/flight ($4.2M/satellite) and generate revenues of $1050M/year (gross profits = $630M/year). Later (in Section 5.5), we will use this RLV price and associated capture in our contrast of RLV-vs-HRLV. The bottomline is that RLV appears to easily pass the entry price barriers -- certainly when compared to ELV.

3.1.2 "Third Wave" Market Example

An example of a future market is space business park/tourism. For this RLV application, we first reviewed the CSTS (Commercial Space Transportation Study) final report. Specifically, we used the study's prediction of cost per passenger as input to our analysis. If we establish a per passenger price of $0.2M, we can then develop a possible business (hotel) park/tourism scenario (see Figure 3-3).

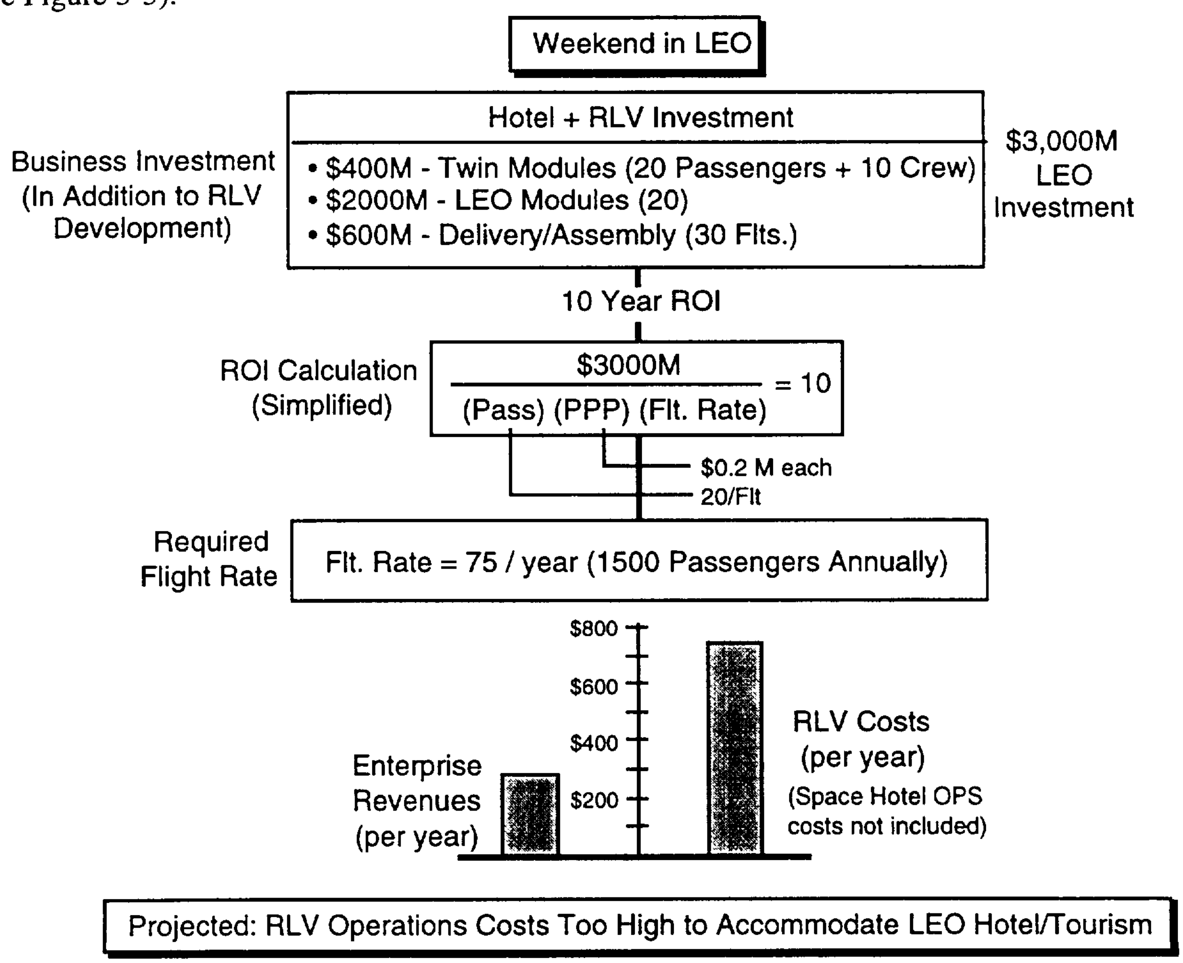


Figure 3-3: Weekend in LEO (Hotel): RLV Unprofitability

The business park example we will consider is "A Weekend in LEO", in which 20 passengers (~10 couples) spend a weekend in LEO at a space hotel. The business investment to develop the hotel/delivery infrastructure is shown in the upper portion of the figure -- about $3000M in total is estimated. The RLV development cost is not even included, nor any investment amortization "tax" (assumed a sunk cost). Hence, this is a very optimistic calculation. Next we calculated a simplified ROI. Thus, we divide the investment ($3000M) by the yearly revenues and demand a 10 year pay back period. From this, we deduce that 75 flights/year (1500 passengers) are required. When bench marked against CSTS, we observe that our requirement far exceeds their nominal forecast of ~750 passengers at $0.2M each. Only if the very optimistic CSTS forecast is used, do we find a reasonable passenger/price correlation. Furthermore, using even $4M/flight for RLV to support the mission (20 paying passengers at $0.2M each), we see that revenues fall short of RLV operation costs. We used $10M/flight for recurring operations. Obviously, we need to slash operating costs dramatically to ensure profitability. To this end, we would propose that the RLV program would carry $50 - $100M annually for P^3I, specifically to reduce recurring operation costs. Even so, we are doubtful that the currently envisioned RLV will be priced sufficiently low enough to enable this market or several other futuristic markets (e.g. nuclear waste disposal, etc.)

Alternately, the introduction of a more advanced ETO system (e.g. HRLV) might have a better probability of bringing down recurring costs. However, reducing recurring costs is important only if it translates into lower customer prices. How well does the HRLV system capture the postulated LEO Hotel market? Figure 3-4 illustrates the previous analysis shown in Figure 3-3, but with HRLV substituted for RLV.

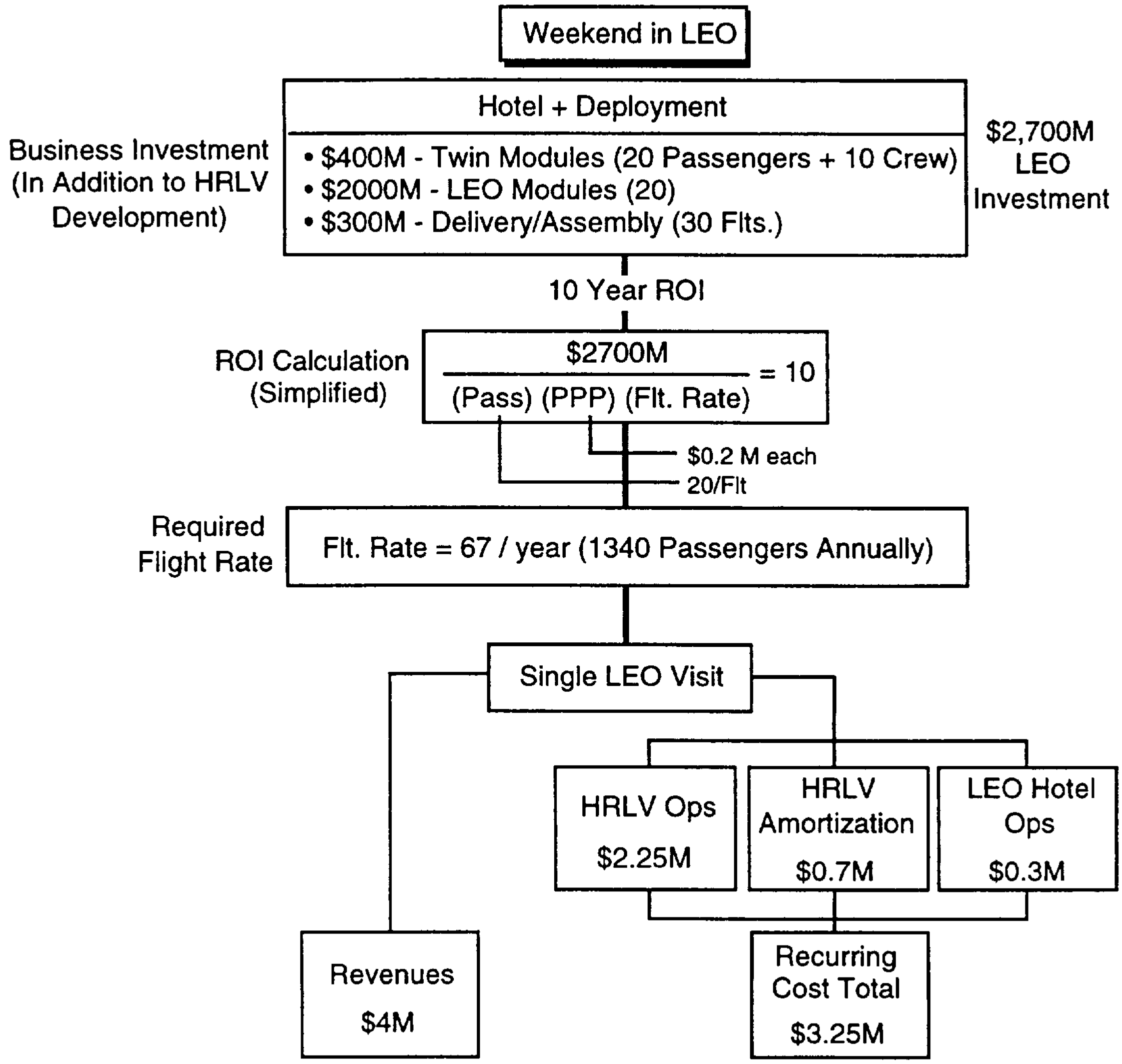


Figure 3-4: Weekend in LEO (Hotel): HRLV Assessment

Because of the lower HRLV system prices, note that the enterprise investment is reduced by $300M to $2700M. As a result, only 67 HRLV tourist flights/year are required. Revenues (per visitation) remain at $4M/flight (~$268M/year). However, the HRLV recurring cost picture is dramatically improved. As shown, about $3.25M/flight (visitation) is needed to operate the HRLV plus LEO Hotel. We have included several recurring cost elements: HRLV ops (see Section 5.2), HRLV amortization, and LEO Hotel ops ($20M/year).

Thus, enterprise revenues exceed outlays (ops costs) by $0.75M/flight, or $1.45M/flight if HRLV amortization is dropped. However, the margin is very delicate. Recall that the CSTS nominal forecast suggests only 38 flights/year, not 67 flights/year. Consequently, the revenue stream is optimistic at best. It may be that $4M/flight is too high a price to charge for 20 passengers.

In the next section, we postulate how a joint USG/Commercial HRST enterprise might occur. The central issue: what will NASA decide to do with future manned space transportation?

4.0 MLV/ILV/HLV-CLASS HRST PROGRAM ASSESSMENT

By the end of the decade, the government must decide on a course of action for manned space flight. Three basic options exist:

- Option 1: NASA and the STS contractor -- USA (United Space Alliance) will continue to maintain the existing STS fleet or
- Option 2: NASA could initiate an STS modernization (NASA procurement) program and thus, continue to rely on the STS, or
- Option 3: Commercial sector that is industry led, government sponsored could develop on its own an RLV (for STS replacement) with a USG loan guarantee and equitable price structure (with USG flight guarantees).

One of these basic options is likely to be selected by the USG before the end of the century. Although it is obviously not possible to prejudge the outcome of this decision, it is possible to critique each. For each of the 3 options, we will overlay a hypothetical HRST program, and measure its budgetary implications for NASA. Only the HRST risk reduction costs (through HRLV prototype) are added to the NASA budget line. For this NASA options analysis actual commercialization is assumed "off budget" (e.g. a commercial development).

Option 1 is the easiest course, but is indecisive and shortsighted. It fails to prudently come to grips with the aging STS issue in a timely manner. It assumes no orbiter losses, additions or replacements. To continue to fly STS without providing for a modernization program is likely to eventually lead to another Challenger catastrophe. In time, NASA would be forced to a new launch vehicle development, or to add significant funding for STS modernization, probably as the result of a national outcry against STS neglect. The financial commitment that NASA will be required to make will surely exceed available funding, and likely drive any new start resembling an HRST beyond its currently scheduled IOC. This is illustrated in Figure 4-1. The actual HRLV "commercial" development (another \$3-5B) is assumed "off budget" (NASA) and is not shown. The HRLV IOC would occur in ~2018-19. If manned space access continues to be central to NASA's mission, then NASA must make a responsible, pro-active STS modernization decision. The status quo option is not a proper course.

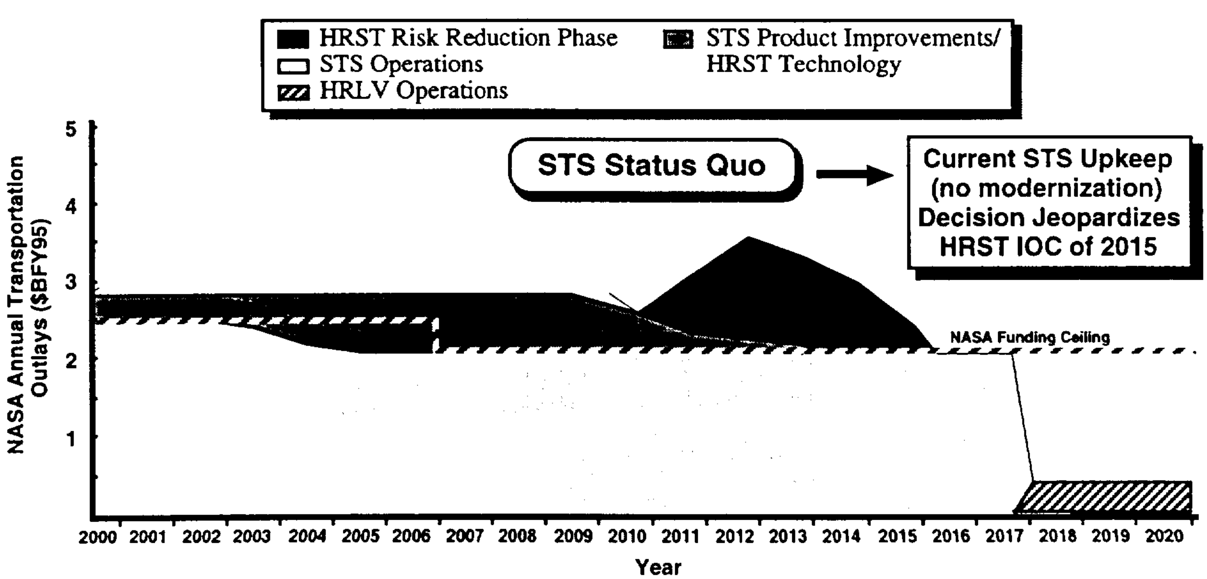


Figure 4-1: Maintain Current STS with No Modernization (Option 1)

Option 2 represents a more meaningful response to STS continuation, but also has critical flaws. Figure 4-2 lays out a notional NASA space transportation funding requirements profile. This profile illustrates that a NASA funded STS modernization would severely overrun the NASA Transportation Ceiling. Several budget components are included: STS Operations (conducted by the NASA STS contractor USA (United Space Alliance), STS P^3I, and a notional STS modernization investment (including a new orbiter). For this analysis we assume that USA succeeds in reducing STS annual operations costs to $2.5B/year by 2000. Additionally, STS P^3I is estimated to be ~$0.3B/year, significantly below today's levels. Next we show how a $3.0B STS modernization might overlay this base; a new orbiter (~$1.5B) comes on line in 2010. The cost benefits of the modernization reveal themselves in a slight lowering of the STS operations cost (2003).

Two problems stand out in Option 2. First, the NREC$ investment is probably too low. Secondly, a new orbiter is likely underestimated. The bottom line is that even this optimistic modernization program is going to far exceed NASA's transportation budget in the 2001-02 time frame — just when the ISS is achieving Permanent Human Capability. And the same problem facing HRLV in Option 1 still remains -- that an overwhelming financial commitment is required by NASA and the subsequent HRLV delayed IOC. Again, the actual HRLV commercial development is off budget. NASA may slip HRLV IOC, given that it was already committed to an STS modernization program. Perhaps an HRLV IOC of 2022 would be appropriate.

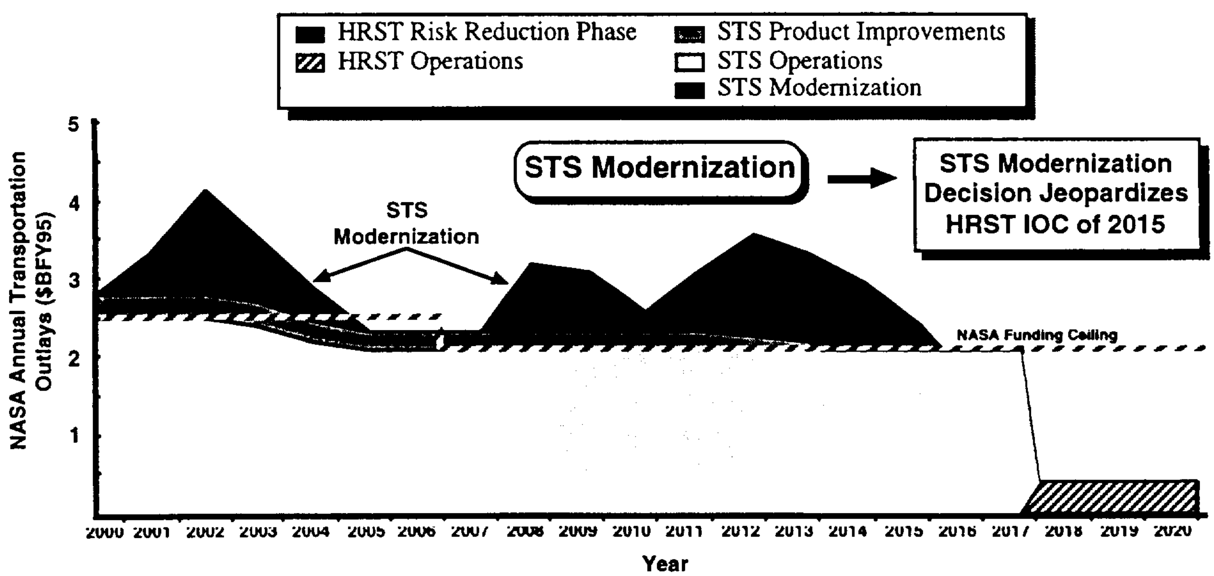


Figure 4-2: STS Modernization Profile (Option 2)

Option 3 represents a commercially developed RLV alternative to STS modernization. Shown in Figure 4-3 is the corresponding NASA funding profile to cover this program option. Note that we have provided budget lines for STS operation, a declining STS P^3I program, NASA ISS infrastructure development, ISS mPLM and Crew Module development/production, and RLV operations to support ISS servicing. Conspicuously absent is any NASA direct funding for RLV development. It is assumed that Lockheed-Martin would commercially develop the RLV system and facilities.

The ISS infrastructure funding represents NASA development/procurement of (1) RLV passenger module ($0.6B) plus (2) mPLM (discussed in Section 4) and other infrastructure additions ($0.3B) to accommodate RLV. Although the STS operations transition to RLV from 2004-06, the estimated STS operation costs do not decrease markedly until 2006. Two fundamental observations about this NASA-industry option include:

- NASA space transportation ceiling exceeded only very slightly ($300M in 2004) compared to STS modernization, and
- NASA realizes significant savings following RLV introduction.

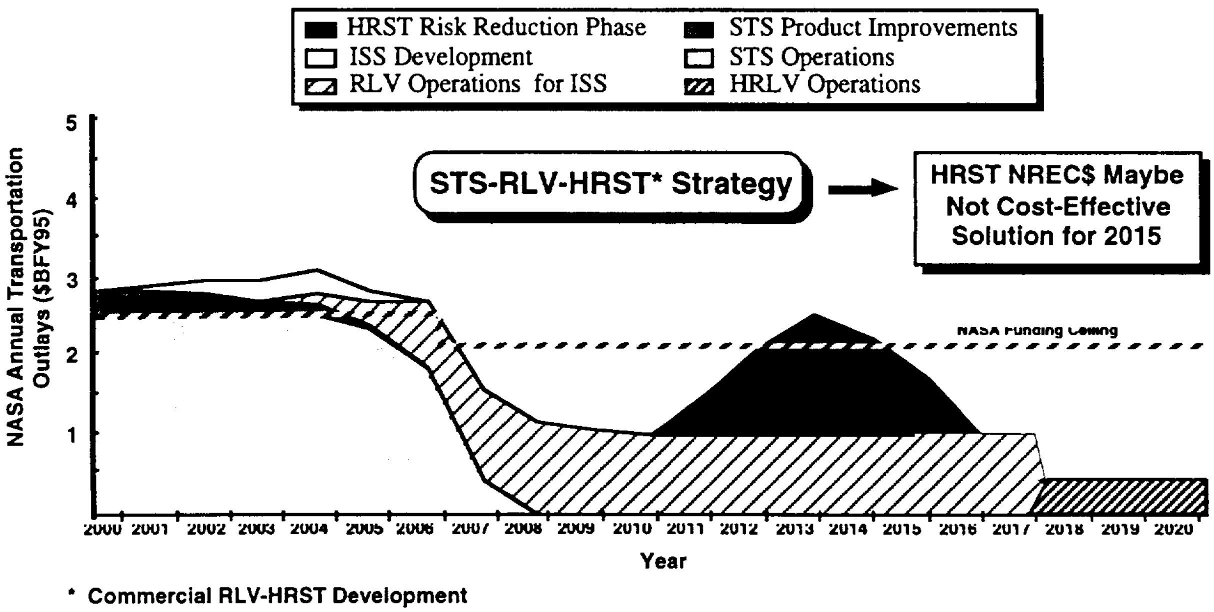


Figure 4-3: A Possible STS-RLV-HRLV Phasing Strategy (Option 3)

A mature RLV system would successfully secure virtually all access-to-space markets addressing MLV/ILV/HLV payload classes, except for Titan IV. Therefore, according to our Vision 2020 studies, targeting a 2015 IOC for HRLV may not appear cost effective to NASA, considering that RLV should be in its prime at that time and for the foreseeable future.

As discussed earlier, does NASA risk reduction funding validate the recurring saving? As an annual recurring cost reduction (in terms of percentage), significant NASA savings result, but absolute savings are much less impressive.

Option 3 appears the most promising of the three HRLV introduction options. Probable events outside the scope of our discussions will also shape the viability and details of HRLV Option 3 (e.g. advanced space station, Lunar/Mars exploration, Mega LEO, etc.) A variation on this option would be to stretch out RLV development (due to further risk reduction requirements) and incorporate selected HRST technologies.

5.0 POTENTIAL HRST OVERLAY: HYPOTHETICAL SCENARIO

5.1 MagLifter plus RBCC RLV

A unique concept for ETO launch is the application of a low-acceleration electromagnetic catapult. Until recently, the basic technologies did not exist to enable the practical pursuit of catapult space launch concepts. However, the development of new technologies may enable such a concept to be applied as a "virtual first stage" for HRLVs and subsequently provide lower operation costs. An acceleration of 3g, provided by stage zero (virtual first stage), significantly increases the effective specific impulse for a wide range of launch vehicles. The concept examined for HRST, and based upon superconducting magnetic levitation (maglev) technology, is known as "MagLifter". We conceptualize an RBCC (rocket-based combined cycle) RLV as the launch vehicle.

The configuration in Figure 5-1 assumes that the RLV launch vehicle can apply aerodynamic lift during launch. The launch vehicle also features an air-breather/rocket combined propulsion system with an assumed GLOW of 1.2 Mlbs at 1200 mph (payload=40 Klbm to LEO).

As a basis, we selected the RLV rocket-based, aerodynamic lifting body which is assumed to have a GLOW of ~2.4 Mlbs. The RBCC RLV, using maglev for stage zero, has a GLOW of 1.2 Mlbs (each technology drops the RLV mass by ~25%). This includes added vehicle reinforcement for robustness (worse mass fraction).

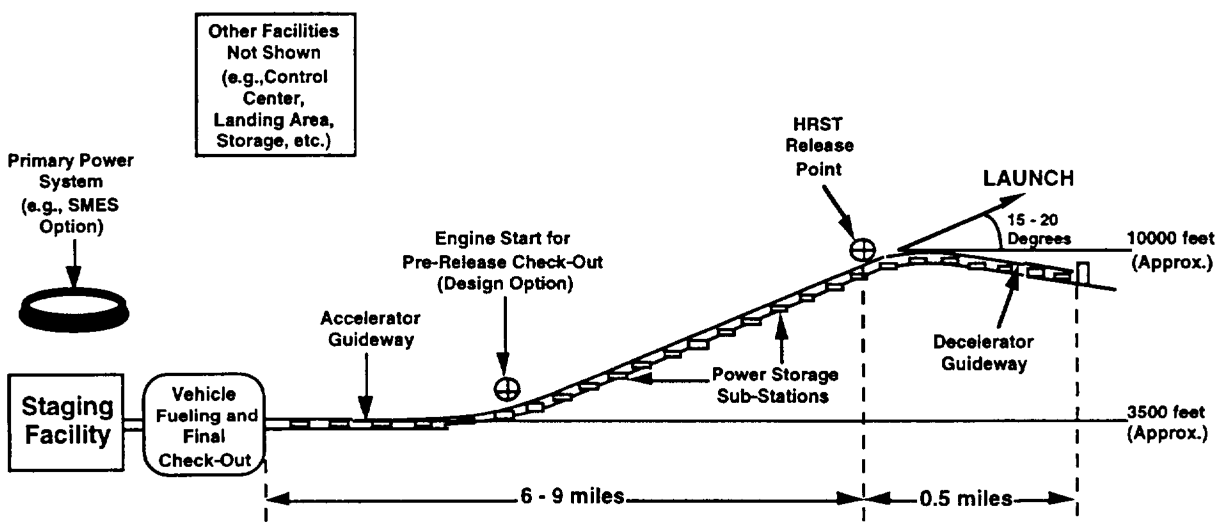


Figure 5-1: MagLifter Operation Concept -- Aerodynamic Lift Application

The unique characteristics of a MagLifter plus RBCC RLV allow a much smaller RLV (~50%) with equivalent delivery. We believe that a low latitude site (say ≤35°N) would accommodate both GTO and Polar missions, although at some performance penalty (for the launch azimuths not aligned with the MagLifter guideway). Adequate recovery landing strips would also have to be closely positioned. Acceptable launch sites and the number of launch guideways are limited by (see Figure 5-2):

- Site terrain, including elevation, slope, availability and power-availability
- Complexity of ground acceleration guideways
- Impact of overflight rules (population, national parks, etc.)
- Site construction and operation costs -- area remoteness
- Desired market base (available guideways determine possible customers)

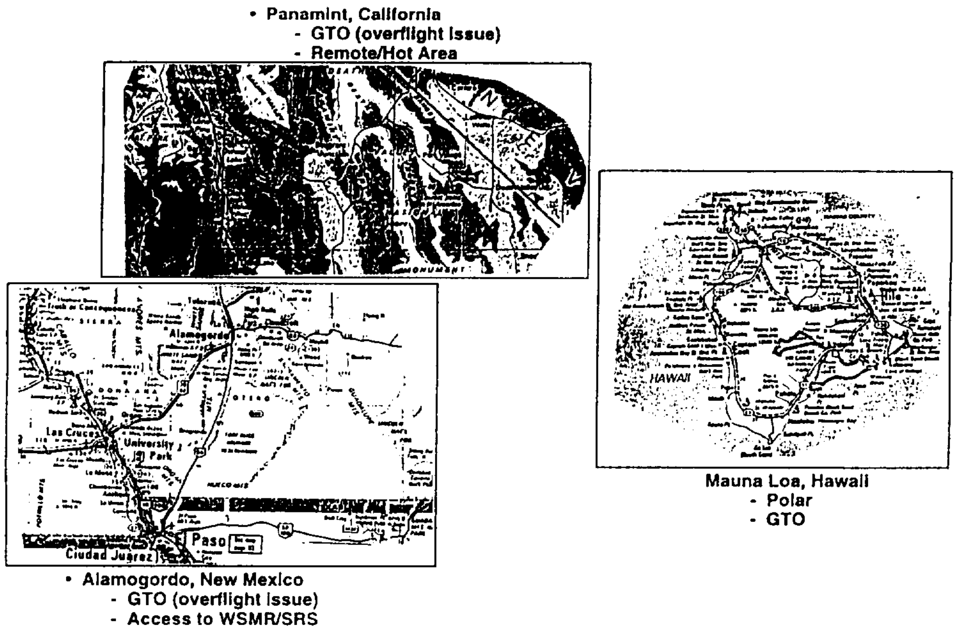


Figure 5-2: Potential US HRLV Launch and Recovery Sites

As shown, we have cursorily identified three potential HRLV launch sites. Anyone of the candidates probably could be groomed for both GTO and Polar missions. The two CONUS sites would have MagLifter guideways oriented in an easterly direction (GTO optimal). The Hawaiian site guideway could be oriented either for Polar or GTO missions. It also has the greatest zero-stage benefits because of its latitude and altitude.

Our operations concept implies a smaller vehicle than current RLV designs (~50% reduction). Though this constitutes a new vehicle development (DDT&E of ~1B and vehicles production ~70% of RLV), the smaller vehicle is predicted to contribute to a savings in RLV operation costs of ~30%. However, this must be weighed against the cost of a MagLifter development (combined DDT&E plus one facility at ~$1B) and its associated operations costs. All costs are optional, but represent optimistic extrapolations from RLV.

The two HRST development options are shown in Figure 5-3. Both are derived from our most plausible scenario of infusing HRST technology into the RLV prior to the latter's IOC.

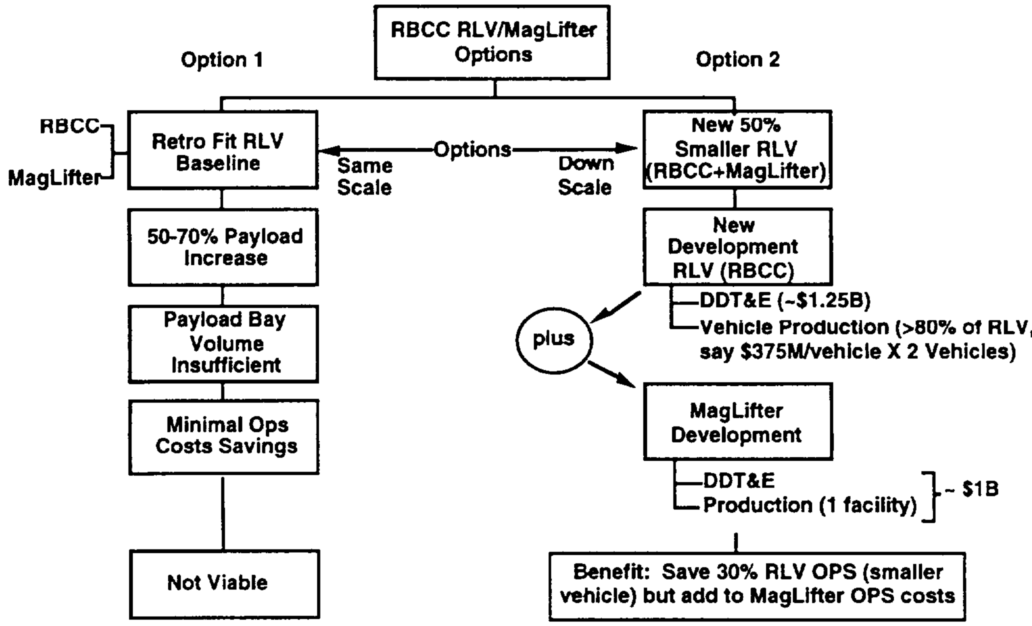


Figure 5-3: *Two HRLV Development Scenarios*

As indicated, the two options differ based upon the vehicle scaling philosophy adopted. Option 1 requires that the basic RLV design be modifiable directly to the HRLV configuration at the same scale. If this is possible, we estimate that the HRST would have a delivery capability 50-75% greater than the baselined RLV (e.g. 60-70 Klbm to LEO). Two problems immediately arise: (1) the payload bay is far too small to accommodate this mass and, even if it could, (2) the vehicle would be overmatched to the market centroid (20-40 Klbm to LEO). For these and other reasons shown, we do not recommend this option.

Option 2 appears far more viable. The pertinent details are shown in Figure 5-3. The basic philosophy here is to down scale the baseline RLV design by ~50% for HRLV. We would even consider adjusting downward the LEO payload (to between 20 to 30 Klbm), if that were a good match to the market payload centroid. In any case, the details of the HRLV development and operations financial picture are highlighted.

Next, we address these issues to determine the true cost-benefit of a combined MagLifter/HRST (RBCC RLV) development and operation, when compared to the proposed RLV.

5.2 HRLV Cost Scenario: Combined MagLifter/RBCC RLV

Consider a scenario for implementing an HRST system based upon the following assumptions (see Figure 5-3):

- HRST technology infusion into RLV Phase III --- program stretchout
- STS modernization effort initiated in 2000 --- phaseout planned for 2013
- A NASA development of ASTP, with a front-loaded investment of $2B over a period from 2002 to 2006 --- not charged to industry
- A follow-on to ASTP leading to a commercial HRST, with a front-loaded investment of $3B over a period from 2007 to 2010 ($2B for RBCC including vehicles and $1B for MagLifter zero stage) --- commercially developed
- HRLV IOC in 2011

Operating costs are based upon delivering 20-40 Klbm payload to LEO by an Atlas-class HRLV with a $100M P^{3}I/year and a pricing schedule of $10M/flight. Operating cost for the HRLV range from $13.7M/flight at 20 flights/year, down to $2.25M/flight at 100 flights/year, after 7 years including P^{3}I. Revenues start in 2011. Our notional HRLV traffic model is shown in Figure 5-4. Because of reduced prices, this base model is approximately twice that of the corresponding RLV model (see Figure 2-8).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
USG	0	10	20	30	30	30	30	30	30	30	30
Commercial	0	10	30	50	50	60	60	70	70	70	80
Cost/Flight [$M FY96]	—	13.7	5.4	3.3	3.0	2.6	2.5	2.2	2.2	2.1	1.9

Figure 5-4: HRLV Notional Traffic Model - 2011 to 2020

The indicated operation costs (cost/flight) reflect both the rate/learning, plus the benefits from the continuing P^{3}I program. Thus, we note that both revenues (flight rate x price) and gross profits ((price - cost) x flight rate) increase over the period of the model. We believe that the very high flight rates are consistent with our pricing structure.

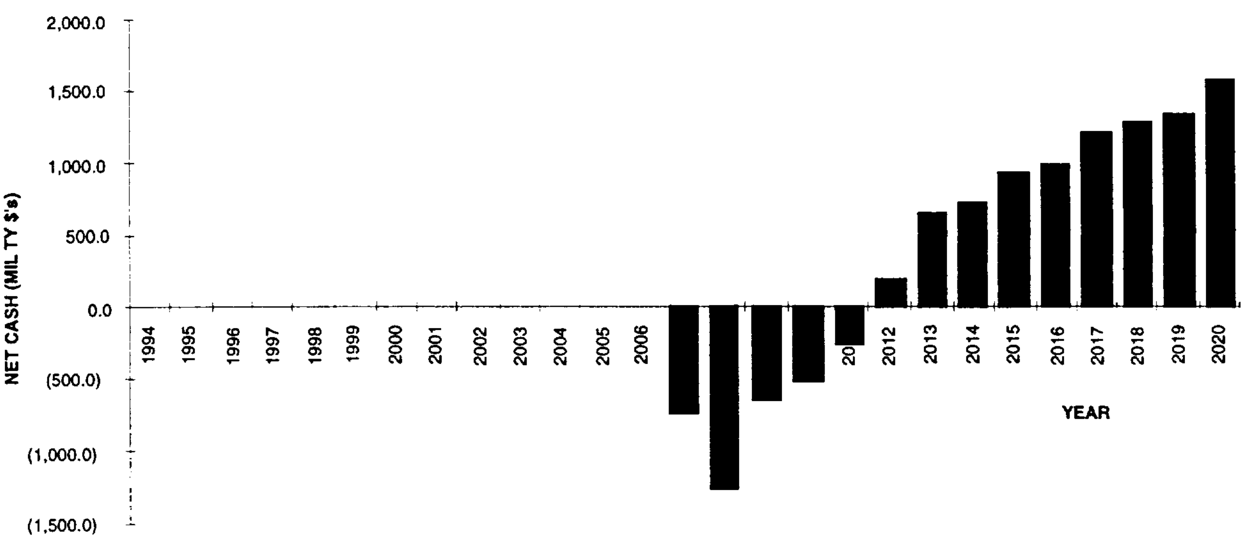


Figure 5-5: HRLV After Tax Cash Flow per Year

Figures 5-5 and 5-6 illustrate two of the financials for our hypothetical HRLV scenarios. The former displays the net cash flow (income minus expenditures) in then year dollars. Note that we have not shown the NASA ASTP technology prototype funding (≥$2B) for RLV (RBCC) plus MagLifter. This funding would occur over a time window of 2002-06. The income stream begins in 2011. Recall that this net income stream is the difference between revenues and operating costs (recurring operations plus P³I). Our total operating costs (~2017 steady state) are best thought of in terms of annual outlays of ~$225M (100 flights), broken out as follows:

• 75 upper stages at ~$0.5M each		= $38M
• Propellants at $0.3M each (100 flights)		= 30
• RLV (RBCC) operations and spares		= 32
• MagLifter operations and spares		= 25
• P³I program		= 100
	TOTAL	= $225M

Many of the cost elements shown above are very optimistic. An increase in upper stage costs to $2.0M each would increase operation costs by 50% alone. HRLV operation costs and spares are also very optimistic. However, this level of operation cost is necessary if we are going to get "cost" to LEO under $100/lbm. This operations cost, including P³I, equate to $116/lbm to LEO. Without P³I, LEO delivery is $83/lbm. Note that customer costs (e.g. price) is ~$333/lbm (e.g. price=$10M for 30 Klbm). Finally, the net cash flows reflect not only the increasing flight traffic, but also the 4% annual inflation rate.

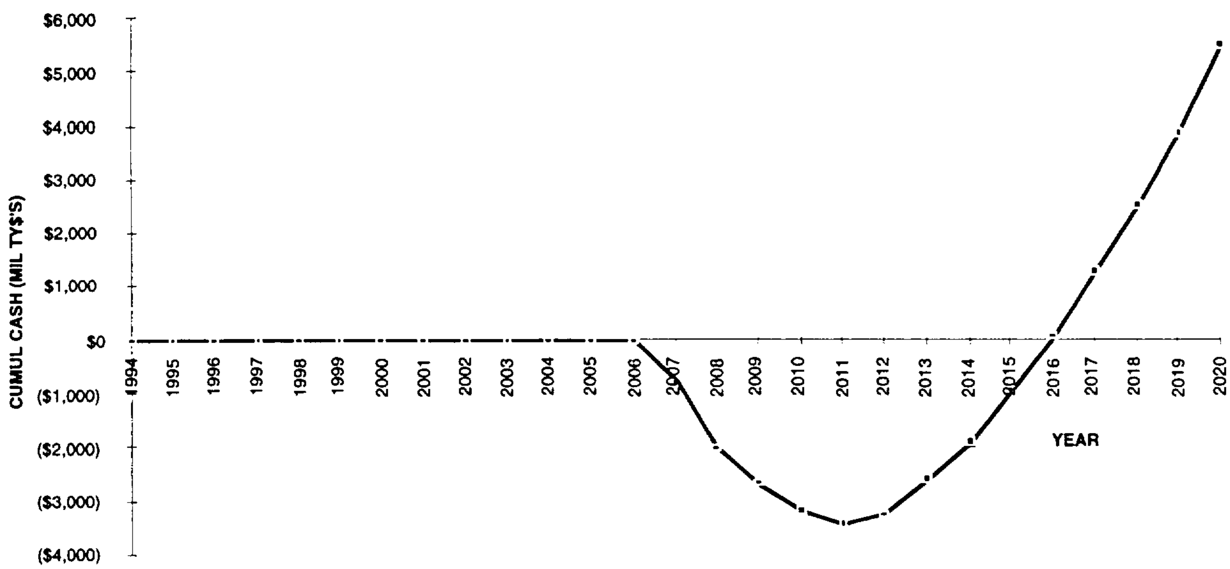


Figure 5-6: HRLV Cumulative After Tax Cash Flow

Figure 5-6 transforms the net cash flows of Figure 5-5 into a cumulative (after tax) cash flow. In turn, Figure 5-7 transforms Figure 5-6 into a cumulative net present value (NPV), where we have discounted the annual outlays/incomes by our notional 20% hurdle rate. This technique discounts the value of money by 20% each year after the beginning of the program (2007). Thus, HRLV revenues in 2011 (four years after HRLV program go ahead) are discounted by ~60% (= ... $1-(1-0.2)^4$!). This hurdle rate calculation is a common commercial technique for measuring the cost-benefit of alternative business investments. The hurdle rate selected by a corporation reflects both missed opportunity costs (other investment possibilities not taken) plus a measure of the candidate program risk (technical, schedule, financial/market).

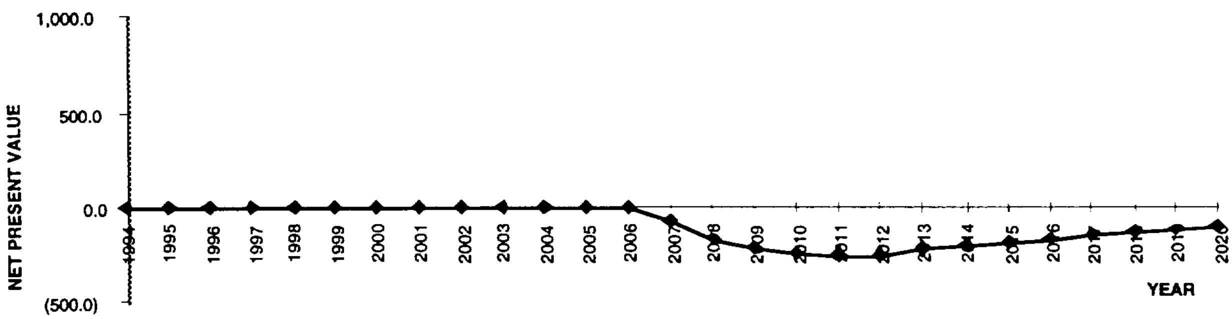


Figure 5-7: HRLV Cumulative Net Present Value

Figure 5-6 reflects the HRLV team's exposure to ~$3000M in 2010-11, with payback occurring in 2016. However, as shown in Figure 5-7, the cumulative NPV does not reach zero, and the HRLV program fails to achieve the required 20% hurdle rate by 2020 (IRR=12.3%). Interestingly, if the commercial HRLV development could be reduced to $1.7B (instead of $3B), then the payback occurs in 2015 and the 20% hurdle rate requirement is achieved in 2020.

Our baseline RLV captures ~56 flights/year (2010-15) at $25M each (see Figure 2-8). RLV operation cost should be ~$7.5M/flight (at this flight rate). The financial details are as follows:

	RLV(56)	HRLV (100)	HRLV (150)
Annual revenues:	$1400M	$1000M	$1200M
Annual operations costs: (includes $100M/year P^3I)	$520M	$225M	$300M
Gross profits:	$880M	$775M	$900M

We conclude that HRLV needs a larger market (>100 flights/year) to be cost-effective compared to RLV. As shown, we estimate that HRLV must capture over 150 flights/year to achieve the same gross profit as RLV. It is unclear as to whether the market is sufficiently elastic such that 150 flights/year at $8M each is a reasonable anticipated growth from our RLV operating point (~56 flights/year at a price of $25M). The assumed HRLV operating costs at this higher flight rate is $2.0M. At this juncture there is simply no way to predict this.

Our bottomline is that the HRLV system represents an meaningful step beyond the RLV system with regard to broadening space access markets. As indicated, HRLV has to effectively triple the RLV's flight rate (to ~150 flights/year) at the assumed prices to be profitable. Additionally, HRLV must find ways to substantially cut development costs. Otherwise, the requisite investment hurdle rate cannot be met. In short, HRLV has to achieve a delicate balance in these various market/financial parameters to be successful. We see the biggest potential winner in this process as the new, growth market customers --- a revolution in space access marketing!

6.0 SLV-CLASS HRLV PROGRAM ASSESSMENT

A major driver in HRLV development is to provide low cost access to space for those markets typically found on an SLV manifest. These are frequently customers with limited budgets, where even the least expensive ETO cost/lbm delivery restricts payloads to less than 1 Klbm. These markets are easily lost by the cost of technology developments.

Consider the following launch traffic scenario for the University Space Research Association (USRA) shown in Figure 6-1. Let us assume that USRA has an annual budget to conduct ETO activity of about \$150M, an optimistic amount considering that most of USRA's activities are funded by NASA grants and contracts, and that the NASA budget is declining.

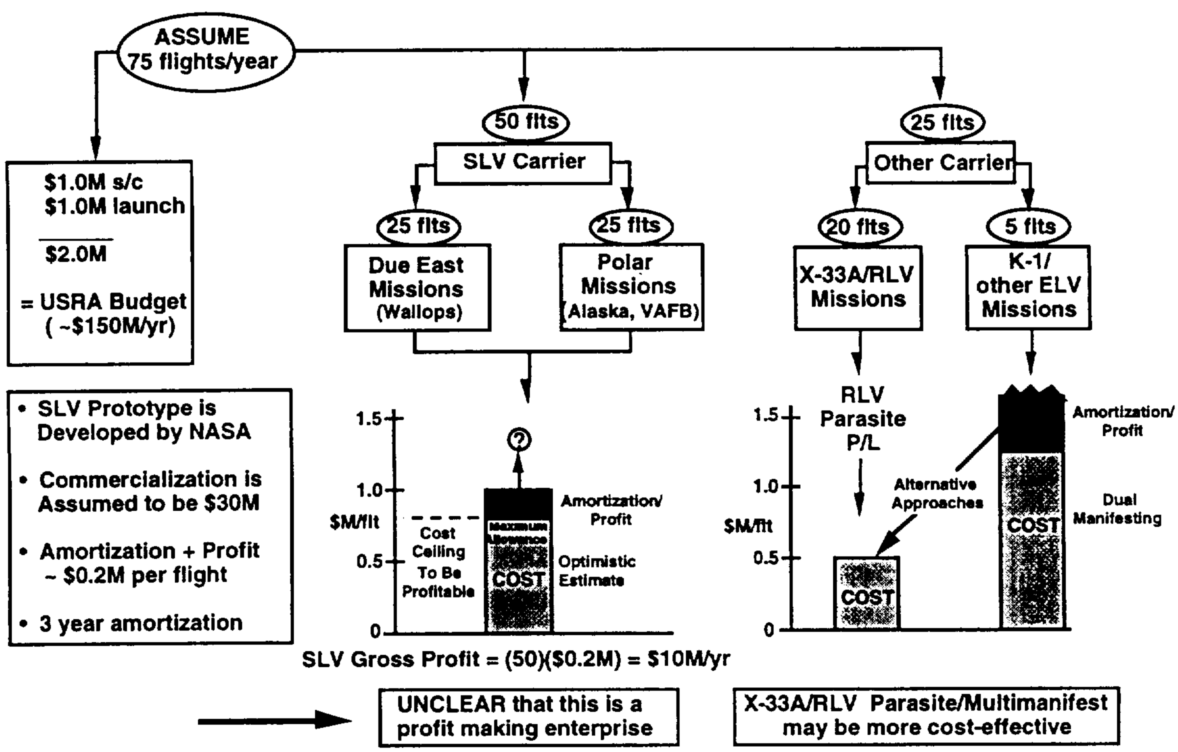


Figure 6-1: SLV Economics -- What Price Risk?

The cost of transportation is the real driver in the academic market. If the cost of a total transportation could be reduced to \$2M (\$1M for payload/spacecraft, \$1M for launch), then a potential 75 flights per year could be achieved by USRA. Of these flights, consider that 50 are dedicated to an SLV-class carrier while other carriers absorb the remaining 25 missions. With an SLV-class system developed by NASA (perhaps within the scope of ASTP), commercialization assumed to be \$30M, and a 3-year amortization, then one looks at a (optimistic) launch return (amortization or gross profit) of about \$0.2M/flight, assuming that no more than the remaining \$0.8M/flight is "lost" to development costs. This leads to a gross "profit" of \$10M/year for 50 flights. The question is whether such a small profit justifies the risk faced in undertaking an SLV-class new start merely to satisfy such a budget-constrained customer.

A more cost-effective alternative may be found in committing numerous payloads (a multi-manifest payload mission) to the launch of a single vehicle in the current inventory (e.g. STS, some other ELV) or one expected to be on-line when the payload need arises (e.g. RLV). Another approach might be in finding payload space on a vehicle already committed to launch for other reasons (a parasite payload mission). Indeed, academia is currently heavily dependent on their payloads being able to "hitch rides" on STS missions (almost for FREE in some cases) in order to afford access to space.

The bottomline is that obtaining a reasonable ROI and profit from a new technology development, often reduces the potential market to the few customers able to afford the new technology's expensive product. Many of the participants within the SLV market cannot afford to underwrite a new launch system. Small payloads frequently reflect small budgets, and in the cost-competitive SLV market there is a greater need, in our opinion, for clever packaging (of planned systems) and marketing than in new technology.

7.0 SUMMARY

In our strategic analysis of the HRLV system, and of the projected global marketplace from which it (or any launch system) must gain its support, we conclude that HRST's viability, as a cost-effective ETO launch system enterprise, is challenged in today's rapid explosion of launch systems. This conclusion is based on:

- The ETO launch industry is currently saturated across the full payload class spectrum. There appears to be little gained by introducing a new system if it does not offer significant differences in cost and operation from what already exists or that is under development (shown in Figure 7-1). HLRV could address this criteria.

- NASA budget projections are not favorable to support simultaneous development of redundant launch systems which service the same customer community. We see HRST technology infusion into RLV as a viable option.

HRST may be best viewed as an insurance policy for RLV. Several of the ASTP technologies could be infused gracefully into RLV (e.g. upper stages).

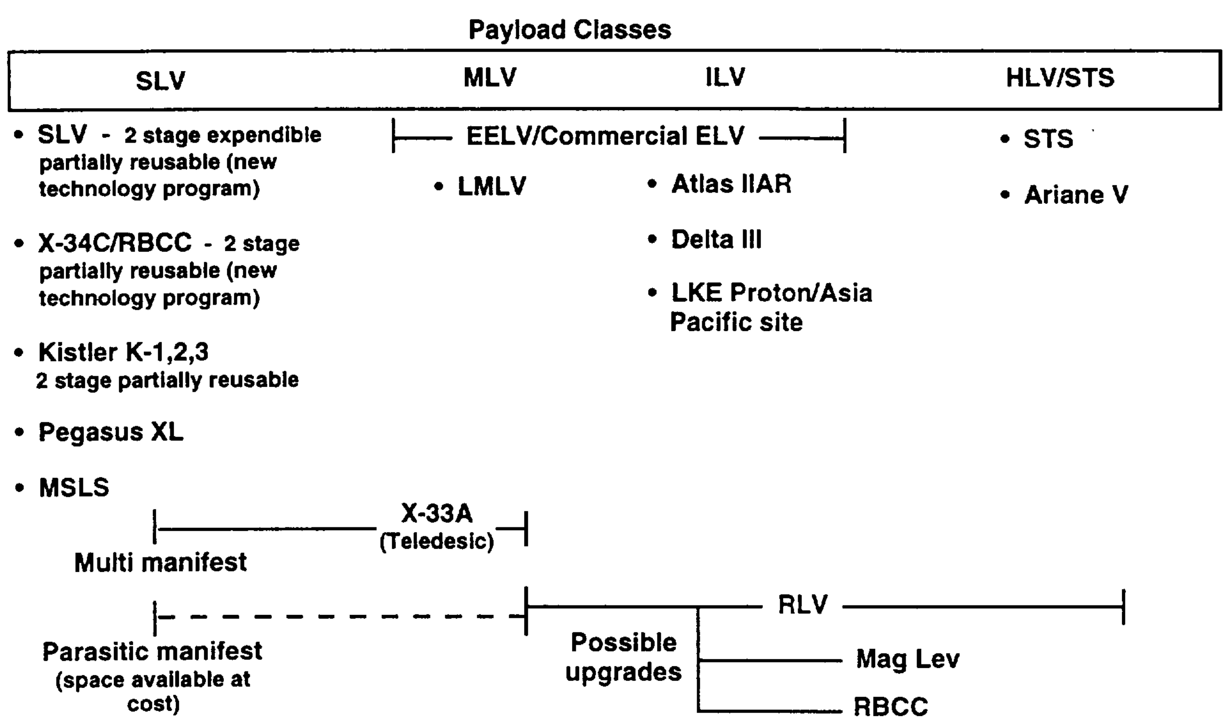


Figure 7-1: Market and Launch Vehicle Matchup

Our preliminary HRST findings include:

- RLV/EELV success greatly facilitate HRST technology infusion.
- ETO development initiatives worldwide currently saturated.
- ASTP technology represents potential components of HRLV or RLV block changes.
- We concur that NASA has identified the best, high payoff ASTP technologies for HRST.
- HRST can be thought of as an overlay to the existing RLV/STS modernization program.
- High HRLV development cost likely requires USG/Industry partnership.
- Confidence in reusable launch systems await X-33/X-34/RLV demonstrations.
  - HRLV operations must be solidly grounded in proven RLV experiences - an HRLV prerequisite.
- HRLV upper stage technology gracefully transitions into RLV.

Our analysis suggests that HRLV has a great potential as a vehicle serving missions beyond LEO, and as such enabling further space exploration. HRST, applied as a modern, low cost upper stage for RLV, could be an invaluable contribution to NASA's centerpiece RLV program. Depending on the success of ASTP propulsion developments, reusability would be invaluable when applied to Orbital Maneuvering Vehicles or Orbital Transfer Vehicles (OMVs, OTVs, space tugs, remote cargo transfer vehicles), improving the operability of any orbiting facility (e.g. ISS, space operations center, space business park) or perhaps improving access to GTO or GSO. The concept could also be applied to advanced transportation systems for Lunar or Mars missions, making such activity more economically favorable.